PART 1

INTRODUCTION

Chapter 1. Project Overview

Harry B. McCarty, Ken Miller, Robert N. Brent, and Judy Schofield
DynCorp (a CSC Company)
601 Stevenson Avene
Alexandrea, Virginia 22304
and
Ronald Rossmann and Kenneth R. Rygwelski
U.S. Environmental Protection Agency
Office of Research and Development
National Health and Environmental Effects Research Laboratory
Mid-Continent Ecology Division
Large Lakes and Rivers Forecasting Research Branch
Large Lakes Research Station
9311 Groh Road
Grosse Ile, Michigan 48138

The United States Environmental Protection Agency's (USEPA) Great Lakes National Program Office (GLNPO) instituted the Lake Michigan Mass Balance Project (LMMBP) to measure and model the concentrations of representative pollutants within important compartments of the Lake Michigan ecosystem. For the LMMBP, concentrations of polychlorinated biphenyls (PCBs), *trans*-nonachlor, atrazine, and mercury in tributaries, lake water, sediments, food webs, and the atmosphere surrounding Lake Michigan were measured. This document contains the PCB modeling results reported by staff and contractors of the USEPA/Office of Research and Development (ORD)/National Health and Environmental Effects Research Laboratory (NHEERL)/Large Lakes and Rivers Forecasting Research Branch (LLRFRB) staff and contractors located at the Large Lakes Research Station (LLRS).

1.1.1 Background

The Great Lakes, which contain 20% of the world's freshwater, are a globally important natural resource currently threatened by multiple stressors. While significant progress has been made to improve the quality of the lakes, pollutant loads from point, non-point, atmospheric, and legacy sources continue to impair ecosystem functions and limit the attainability of designated uses of these resources. Fish consumption advisories and beach closings continue to be issued, emphasizing the human health concerns from lake contamination. Physical and biological stressors, such as invasion of non-native species and habitat loss, also continue to threaten the biological integrity of the Great Lakes.

The United States and Canada have recognized the significance and importance of the Great Lakes as a natural resource and have taken steps to restore and protect the lakes. In 1978, both countries signed the Great Lakes Water Quality Agreement (GLWQA). This Agreement calls for the restoration and maintenance of the chemical, physical, and biological integrity of the Great Lakes by developing plans to monitor and limit pollutant flows into the lakes.

The GLWQA, as well as Section 118(c) of the Clean Water Act, require the development of a Lake-wide Management Plan (LaMP) for each Great Lake. The purpose of these LaMPs is to document an approach to reduce inputs of critical pollutants to the Great

Lakes and restore and maintain Great Lakes integrity. To assist in developing these LaMPs and to monitor progress in pollutant reduction, Federal, State, Tribal, and local entities have instituted Enhanced Monitoring Plans (EMPs). Monitoring is essential to the development of baseline conditions for the Great Lakes and provides a sound scientific base of information to guide future toxic load reduction efforts.

The LMMBP is a part of the EMPs for Lake Michigan. The LMMBP was a coordinated effort among Federal, State, and academic scientists to monitor tributary and atmospheric pollutant loads, develop source inventories of toxic substances, and evaluate the fates and effects of these pollutants in Lake Michigan. A mass balance modeling approach provides the predictive ability to determine the environmental benefits of specific load reduction scenarios for toxic substances and the time required to realize those benefits. This predictive ability will allow Federal, State, Tribal, and local agencies to make more informed load reduction decisions.

1.1.2 Description

The LMMBP used a mass balance approach to evaluate the sources, transport, and fate of contaminants in the Lake Michigan ecosystem. A mass balance approach is based on the law of conservation of mass, which states that the amount of a pollutant entering a system is equal to the amount of that pollutant leaving, trapped in, and chemically changed in the system (Figure 1.1.1). In the Lake Michigan system, pollutant inputs may come from atmospheric deposition or tributary loads.

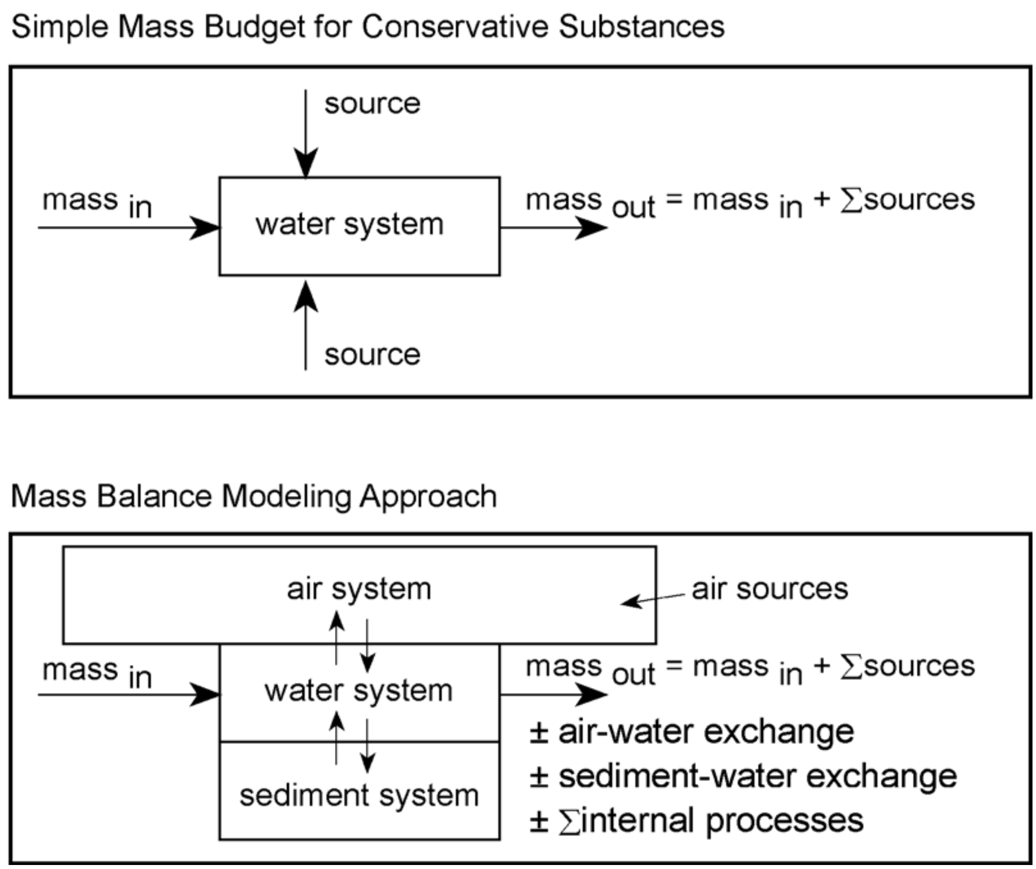

Figure 1.1.1. Simplified mass balance approach.

Pollutants may leave the system through burial in bottom sediments, volatilization to the atmosphere, or discharge into Lake Huron through the Straits of Mackinaw. Pollutants within the system may be transformed through degradation or stored in ecosystem compartments such as the water column, sediments, or biota.

For the LMMBP, contaminant concentrations in various inputs and ecosystem compartments over spatial and temporal scales were measured. Mathematical models that track the transport and fate of contaminants within Lake Michigan were developed and calibrated using these field data. The LMMBP was the first lake-wide application of a mass balance determination for the Great Lakes and will serve as a basis for future mass budget/mass balance efforts.

1.1.3 Scope

1.1.3.1 Modeled Pollutants

When the USEPA published the Water Quality Guidance for the Great Lakes System (58 FR 20802), the Agency established water quality criteria for 29 pollutants. Those criteria were designed to protect aquatic life, terrestrial wildlife, and human health. PCBs, *trans*-nonachlor, and mercury are included in the list of 29 pollutants. The water quality criteria and values proposed in the guidance apply to all of the ambient waters of the Great Lakes System, regardless of the sources of pollutants in those waters. The proposed criteria provide a uniform basis for integrating Federal, State, and Tribal efforts to protect and restore the Great Lakes ecosystem.

The number of pollutants that can be intensively monitored and modeled in the Great Lakes System is limited by the resources available to collect and analyze thousands of samples, assure the quality of the results, manage the data, and develop and calibrate the necessary models. Therefore, the LMMBP focused on constructing mass balance models for a limited group of pollutants. PCBs, *trans*-nonachlor, atrazine, and mercury were selected for inclusion in the LMMBP because these pollutants currently or potentially pose a risk to aquatic and terrestrial organisms (including humans) in the Lake Michigan ecosystem (Table 1.1.1). These pollutants also were selected to cover a wide range of chemical and physical properties and represent other classes of compounds which pose current or potential problems. Once a mass budget for selected pollutants is established and a mass balance model calibrated, additional contaminants can be modeled with limited data and future resources can be devoted to activities such as emission inventories and dispersion modeling.

1.1.3.1.1 PCBs

Polychlorinated biphenyls (PCBs) are a class of man-made, chlorinated, organic chemicals that include 209 congeners, or specific PCB compounds. The highly stable, nonflammable, non-conductive properties of these compounds made them useful in a variety of products including electrical transformers and capacitors, plastics, rubber, paints, adhesives, and sealants. PCBs were produced for such industrial uses in the form of complex mixtures under the trade name “Aroclor” and were commercially available from 1930 through 1977, when the USEPA banned their production due to environmental and public health concerns. PCBs also may be produced by combustion processes, including incineration, and can be found in stack emissions and ash from incinerators.

Because they were found by the USEPA in the effluents from one or more wastewater treatment facilities, seven Aroclor formulations were included in the Priority Pollutant List developed by the USEPA Office of Water under the auspices of the Clean Water Act. Aroclors may have entered the Great Lakes through other means, including spills or improper disposal of transformer fluids, contaminated soils washing into the watershed, or discharges from ships. The PCBs produced by combustion processes may be released to the atmosphere where they are transported in both vapor and particulate phases and enter the lakes through either dry deposition or precipitation events (e.g., rain).

The stability and persistence of PCBs, which made them useful in industrial applications, have also made these compounds ubiquitous in the environment. PCBs do not readily degrade and thus accumulate in water bodies and aquatic sediments. PCBs also bioaccumulate, or build up, in living tissues. Levels of PCBs in some fish from Lake Michigan exceed U.S. Food and Drug Administration tolerances,

Table 1.1.1. Characteristics of the LMMBP Modeled Pollutants

Pollutant	Sources	Uses	Toxic Effects	Bioconcentration Factor[1]	USEPA Regulatory Standards[2]
PCBs	• Waste incinerators (unintentional byproducts of combustion) • Industrial dischargers • Electrical power	• Electrical transformers and capacitors • Carbonless copy paper • Plasticizers • Hydraulic fluids	• Probable human carcinogen • Hearing and vision impairment • Liver function alterations • Reproductive impairment and deformities in fish and wildlife	1,800 to 180,000	MCL = 0.5 µg/L CCC = 14 ng/L HH = 0.17 ng/L
trans-Nonachlor[3]	• Application to crops and gardens	• Pesticide on corn and citrus crops • Pesticide on lawns and gardens	• Probable human carcinogen • Nervous system effects • Blood system effects • Liver, kidney, heart, lung, spleen, and adrenal gland damage	4,000 to 40,000	MCL = 2 µg/L CMC = 2.4 µg/L CCC = 4.3 ng/L HH = 2.1 ng/L
Atrazine	• Application to crops	• Herbicide for corn and sorghum production	• Weight loss • Cardiovascular damage • Muscle and adrenal degeneration • Congestion of heart, lungs, and kidneys • Toxic to aquatic plants	2 to 100	MCL = 3 µg/L CMC[4] = 350 µg/L CCC[4] = 12 µg/L
Mercury	• Waste disposal • Manufacturing processes • Energy production • Ore processing • Municipal & medical waste incinerators • Chloralkali factories • Fuel combustion	• Battery cells • Barometers • Dental fillings • Thermometers • Switches • Fluorescent lamps	• Possible human carcinogen • Damage to brain and kidneys • Adverse affects on the developing fetus, sperm, and male reproductive organs	63,000 to 100,000	MCL = 2 µg/L CMC = 1.4 µg/L CCC = 0.77 µg/L HH = 50 ng/L FWA[5] = 2.4 µg/L FWC[5] = 12 ng/L Wildlife[6] = 1.3 ng/L

[1]From: U.S. Environmental Protection Agency, 1995a, National Primary Drinking Water Regulations, Contaminant Specific Fact Sheets, Inorganic Chemicals, Technical Version, EPA 811/F-95/002-T, USEPA, Office of Water, Washington, D.C.; and U.S. Environmental Protection Agency, 1995b, National Primary Drinking Water Regulations, Contaminant Specific Fact Sheets, Synthetic Organic Chemicals, Technical Version, EPA 811/F-95/003-T, USEPA, Office of Water, Washington, D.C.

[2]MCL = Maximum Contaminant Level for drinking water. CMC = Criterion Maximum Concentration for protection of aquatic life from acute toxicity. CCC = Criterion Continuous Concentration for protection of aquatic life from chronic toxicity. HH = water quality criteria for protection of human health from water and fish consumption. Data from: U.S. Environmental Protection Agency, 1999, National Recommended Water Quality Criteria-Correction, EPA 822/Z-99/001, USEPA, Office of Water, Washington, D.C.

[3]Characteristics presented are for chlordane. *trans*-Nonachlor is a principle component of the pesticide chlordane.

[4]Draft water quality criteria for protection of aquatic life. From: U.S. Environmental Protection Agency, 2001b, Ambient Aquatic Life Water Quality Criteria for Atrazine, USEPA, Office of Water, Washington, D.C.

[5]FWA = Freshwater acute water quality criterion. FWC = Freshwater chronic water quality criterion. From National Toxics Rule (58 FR 60848).

[6]Wildlife criterion. From the Stay of Federal Water Quality Criteria for Metals (60 FR 22208), 40 CFR 131.36 and the Water Quality Guidance for the Great Lakes System (40 CFR 132).

prompting closure of some commercial fisheries and issuance of fish consumption advisories. PCBs are a probable human carcinogen, and human health effects of PCBs exposure include stomach, kidney, and liver damage; liver and biliary tract cancer; and reproductive effects, including effects on the fetus after exposure of the mother.

PCB congeners exhibit a wide range of physical and chemical properties (e.g. vapor pressures, solubilities, boiling points), are relatively resistant to degradation, and are ubiquitous. These properties make them ideal surrogates for a wide range of organic compounds from anthropogenic sources.

1.1.3.1.2 Isomer trans-Nonachlor

The isomer *trans*-nonachlor is a component of the pesticide chlordane. Chlordane is a mixture of chlorinated hydrocarbons that was manufactured and used as a pesticide from 1948 to 1988. Prior to 1983, approximately 3.6 million pounds of chlordane were used annually in the United States. In 1988, the USEPA banned all production and use of chlordane in the United States.

Like PCBs, chlordane is relatively persistent and bioaccumulative. The *trans*-nonachlor is the most bioaccumulative of the chlordanes, and is a probable human carcinogen. Other human health effects include neurological effects, blood dyscrasia, hepatoxicity, immunotoxicity, and endocrine system disruption.

Historically, *trans*-nonachlor may have entered the Great Lakes through a variety of means related to the application of chlordane, including improper or indiscriminate application, improper cleaning and disposal of pesticide application equipment, or contaminated soils washing into the watershed. In the LMMBP, *trans*-nonachlor served as a model for the cyclodiene pesticides.

1.1.3.1.3 Atrazine

Atrazine is a triazine herbicide based on a ring structure with three carbon atoms alternating with three nitrogen atoms. Atrazine is the most widely used herbicide in the United States for corn and sorghum production. Atrazine has been used as an agricultural herbicide since 1959, and 64 to 75 million pounds of atrazine are used annually in the United States. Atrazine is extensively used in the upper Midwest, including the Lake Michigan watershed, where it is primarily associated with corn crops.

Unlike PCBs and *trans*-nonachlor, atrazine is not bioaccumulative. It is persistent in water; however, it is moderately susceptible to biodegradation in soils with a half-life of about 60-150 days. Atrazine rarely exceeds the 3 ppb maximum contaminant level (MCL) set by the USEPA as a drinking water standard, but localized peak values can exceed the MCL following rainfall events after atrazine application.

In January 31, 2003, the U.S. EPA issued an Interim Reregistration Eligibility Decision (IRED) for atrazine. In an October 2003 addendum to the IRED, the agency concluded that there is sufficient evidence to formulate a hypothesis that atrazine exposure may impact gonadal development in amphibians, but there are currently insufficient data to either confirm or refute the hypothesis. Based on available test data, atrazine is not likely to be a human carcinogen. The Agency does have concern in regards to the potential hormonal effects observed in laboratory animals exposed to atrazine. Above certain concentration thresholds, atrazine is toxic to aquatic plants. In the LMMBP, atrazine served as a model to describe the transport and fate of a water-soluble pesticide in current use.

1.1.3.1.4 Mercury

Mercury is a naturally-occurring toxic metal. Mercury is used in battery cells, barometers, thermometers, switches, fluorescent lamps, and as a catalyst in the oxidation of organic compounds. Global releases of mercury in the environment are both natural and anthropogenic (caused by human activity). It is estimated that about 11,000 metric tons of mercury are released annually to the air, soil, and water from anthropogenic sources. These sources include combustion of various fuels such as coal; mining, smelting and manufacturing activities; wastewater; and agricultural, animal, and food wastes.

As an elemental metal, mercury is extremely persistent in all media. Mercury also bioaccumulates with reported bioconcentration factors in fish tissues in the range of 63,000 to 100,000. Mercury is a possible human carcinogen and causes the following human health effects: stomach, large intestine, brain, lung, and kidney damage; blood pressure and heart rate increase; and fetal damage. In the LMMBP, mercury served as a model for bioaccumulative metals.

1.1.3.2 Other Measured Parameters

In addition to the four chemicals modeled in the LMMBP, many other chemicals and parameters were measured in the LMMBP as part of the EMPs. A survey of these chemicals and parameters aids in the understanding of the overall ecological integrity of Lake Michigan. These additional parameters include various biological indicators; meteorological parameters; and organic, metal, and conventional chemicals in Lake Michigan. A complete listing of parameters included in this study is provided in Table 1.1.2. A comprehensive listing of parameters and compartments may be found in Chapter 3 (Appendix 1.3.1).

1.1.3.3 Measured Compartments

In the LMMBP, contaminants were measured in the following compartments:

- **Open Lake Water Column:** The water column in the open lake was sampled and analyzed for the modeled pollutants.

- **Tributaries:** Major tributaries were sampled and analyzed for the modeled pollutants.

- **Fish:** Top predators and forage base species were sampled and analyzed for diet analysis and contaminant burden.

- **Lower Pelagic Food Chain:** Phytoplankton and zooplankton were sampled and analyzed for species diversity, taxonomy, and contaminant burden.

- **Sediments**: Cores were collected and trap devices were used to collect sediment for determination of contaminants and sedimentation rates.

- **Atmosphere:** Vapor, particulate, and precipitation phase samples were collected and analyzed for the modeled pollutants.

For the modeled pollutants, more than 20,000 samples were collected at more than 300 sampling locations and analyzed, including more than 9,000 quality control (QC) samples (Figure 1.1.2). Field data collection activities were initially envisioned as a one-year effort. However, it became evident early into the project that a longer collection period would be necessary to provide a full year of concurrent information on contaminant loads and ambient concentrations for modeling purposes. Therefore, field sampling occurred from April 1994 to October 1995.

1.1.4 Objectives

The goal of the LMMBP was to develop a sound, scientific base of information to guide future toxic load reduction efforts at the Federal, State, Tribal, and local levels. To meet this goal, the four following LMMBP objectives were developed:

- **Estimate pollutant loading rates:** Environmental sampling of major media will allow estimation of relative loading rates of critical pollutants to the Lake Michigan Basin.

- **Establish baseline:** Environmental sampling and estimated loading rates will establish a baseline against which future progress and contaminant reductions can be gauged.

- **Predict benefits associated with load reductions:** The completed mass balance model will provide a predictive tool that environmental decision-makers and managers may use to evaluate the benefits of specific load reduction scenarios.

- **Understand ecosystem dynamics:** Information from the extensive LMMBP monitoring and modeling efforts will improve our scientific understanding of the environmental processes governing contaminant cycling and availability within relatively closed ecosystems.

Table 1.1.2. The LMMBP Parameters

Organics	
acenaphthene	*p,p'*-DDT
acenaphthylene	endosulfan sulfate
aldrin	endosulfan I
anthracene	endosulfan II
atrazine	endrin
α-BHC	endrin aldehyde
β-BHC	endrin ketone
δ-BHC	fluoranthene
γ-BHC	fluorene
benzo[*a*]anthracene	heptachlor
benzo[*g,h,i*]perylene	heptachlor epoxide
benzo[*b*]fluoranthene	hexachlorobenzene (HCB)
benzo[*k*]fluoranthene	indeno[1,2,3-*cd*]pyrene
benzo[*e*]pyrene	mirex
benzo[*a*]pyrene	*trans*-nonachlor
α-chlordane	oxychlordane
γ-chlordane	PCBs congeners
chrysene	phenanthrene
coronene	pyrene
p,p'-DDE	retene
p,p'-DDD	toxaphene

Metals	
aluminum	magnesium
arsenic	manganese
calcium	sodium
cadmium	nickel
chromium	lead
cesium	selenium
copper	thorium
iron	titanium
mercury	vanadium
potassium	zinc

Conventionals	
alkalinity	particulate organic carbon
ammonia	percent moisture
bromine	pH
chloride	phosphorus
chlorine	silica
sulfate	silicon
conductivity	temperature
dissolved organic carbon	total Kjeldahl nitrogen
	total organic carbon
dissolved oxygen	total phosphorus
dissolved phosphorus	total suspended particulates
dissolved reactive silica	

Conventionals (Continued)	
dry weight fraction	*ortho*-phosphorus
element carbon	total hardness
nitrate	turbidity

Biologicals	
fish species	fish weight
fish age	fish length
fish maturity	fish taxonomy
chlorophyll *a*	fish diet analysis
fish lipid amount	primary productivity
zooplankton	

Meteorological	
air temperature	wind direction
relative humidity	wind speed
barometric pressure	visibility
weather conditions	wave height and direction

1.1.5 Design

1.1.5.1 Organization

The GLNPO proposed a mass balance approach to provide coherent, ecosystem-based evaluation of toxics in Lake Michigan. GLNPO served as the program sponsor for the LMMBP. GLNPO formed two committees to coordinate study planning, the Program Steering Committee and the Technical Coordinating Committee. These committees were comprised of Federal, State, and academic laboratories as well as commercial laboratories (see Section 1.1.5.2, Study Participants). The committees administered a wide variety of tasks including: planning the project, locating the funding, designing the sample collection, coordinating sample collection activities, locating qualified laboratories, coordinating analytical activities, assembling the data, assuring the quality of the data, assembling skilled modelers, developing the models, and communicating interim and final project results. The Mid-Continent Ecology Division (MED) at Duluth, in cooperation with the National Oceanic and Atmospheric Administration (NOAA) Great Lakes Environmental Research Laboratory (GLERL) and the Atmospheric Sciences Modeling Division, supported the modeling component of the mass balance study by developing a suite of integrated mass balance models to

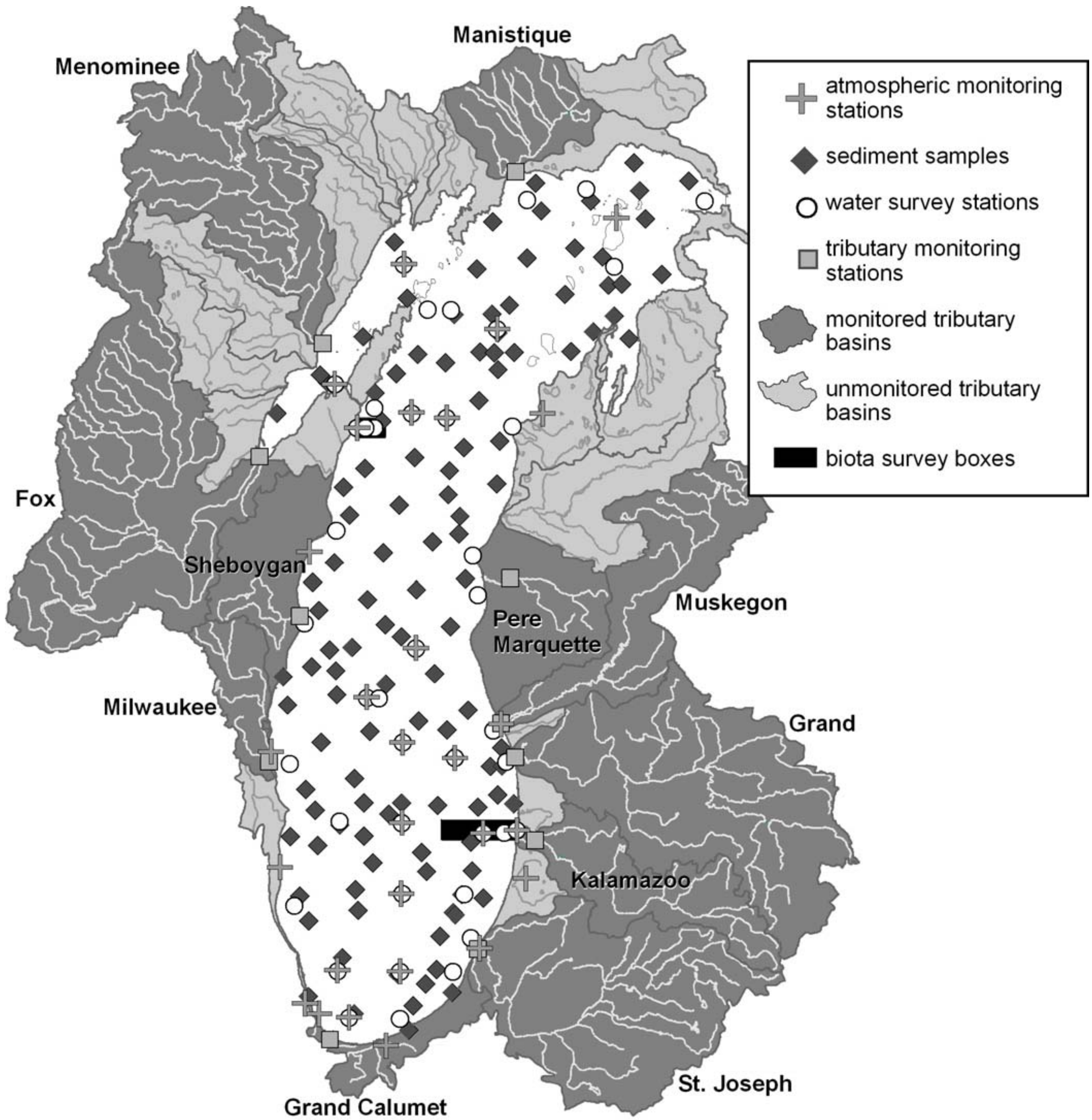

Figure 1.1.2. The LMMBP sampling locations.

simulate the transport, fate, and bioaccumulation of the study target analytes.

1.1.5.2 Study Participants

The LMMBP was a coordinated effort among Federal, State, and academic scientists; and commercial laboratories. The following agencies and organizations have all played roles in ensuring the success of the LMMBP. Except for the three organizations indicated with an asterisk (*), all of the participants were members of the LMMBP Steering Committee.

Federal and International

- USEPA GLNPO (*Program Sponsor*)
- USEPA Region V Water Division (WD)
- USEPA Region V Air Division
- USEPA/ORD/NHEERL/MED/LLRFRB
- ORD National Exposure Research Laboratory
- U.S. Department of Interior (USDOI) U.S. Geological Survey (USGS) Water Resources Division (WRD)
- USDOI/USGS Biological Resources Division Great Lakes Science Center (GLSC)
- U.S. Fish and Wildlife Service (USFWS)
- U.S. Department of Energy
- U.S. Department of Commerce NOAA/GLERL
- USEPA Office of Air and Radiation*
- USEPA Office of Water*
- Environment Canada*
- U.S. Department of Energy Battelle NW

State

- Illinois Department of Natural Resources
- Illinois Water Survey
- Indiana Department of Environmental Management
- Michigan Department of Natural Resources
- Michigan Department of Environmental Quality (MDEQ)
- Wisconsin Department of Natural Resources
- Wisconsin State Lab of Hygiene

Academic and Commercial

- Indiana University
- Rutgers University
- University of Maryland
- University of Michigan
- University of Minnesota
- University of Wisconsin
- Grace Analytical

1.1.5.3 Workgroups

Eleven workgroups were formed to provide oversight and management of specific project elements. The workgroups facilitated planning and implementation of the study in a coordinated and systematic fashion. The workgroups communicated regularly through participation in monthly conference calls and annual "all-hands" meetings. Workgroup chairs were selected and were responsible for managing tasks under the purview of the workgroup and communicating the status of activities to other workgroups. The workgroups and workgroup chairs are listed below.

- Program Steering Committee – Paul Horvatin (USEPA/GLNPO)
- Technical Coordinating Committee – Paul Horvatin (USEPA/GLNPO)
- Modeling Workgroup – William Richardson (USEPA/ORD/NHEERL/MED/LLRFRB)
- Air Monitoring Workgroup – Jackie Bode (USEPA/GLNPO)
- Biota Workgroup – Paul Bertram (USEPA/GLNPO) and John Gannon (USDOI/USGS/GLSC)
- Chemistry Workgroup – David Anderson (USEPA/GLNPO)
- Data Management Workgroup – Kenneth Klewin and Philip Strobel (USEPA/GLNPO)
- Lake Monitoring Workgroup – Glenn Warren (USEPA/GLNPO)
- Tributary Monitoring Workgroup – Gary Kohlhepp (USEPA/Region V/WD) and Robert Day (MDEQ)
- Quality Assurance Workgroup – Louis Blume and Michael Papp (USEPA/GLNPO)
- Sediment Monitoring Workgroup – Brian Eadie (NOAA/GLERL)

1.1.5.4 Information Management

As program sponsor, GLNPO managed information collected during the LMMBP. Principal Investigators (PIs) participating in the study reported field and analytical data to GLNPO. GLNPO developed a data standard for reporting field and analytical data and a database for storing and retrieving study data.

GLNPO was also responsible for conducting data verification activities and releasing verified data to the study modelers and the public. The flow of information is illustrated in Figure 1.1.3.

1.1.5.4.1 Data Reporting

Over 20 organizations produced LMMBP data through the collection and analysis of more than 20,000 samples. In the interest of standardization, specific formats (i.e., file formats and codes to represent certain data values) were established for reporting the LMMBP data. Each format specified the "rules" by which data were submitted, and, in many cases, the allowable values by which they were to be reported. The data reporting formats were designed to minimize the number of data elements reported from the field crews and laboratory analysis. Data reporting formats and the resulting Great Lakes Environmental Monitoring Database (GLENDA, see Section1.1.5.4.2) were designed to be applicable to projects outside the LMMBP as well.

Principal Investigators (including sampling crews and the analytical laboratories) supplied sample collection and analysis data following the standardized reporting formats, if possible. The LMMBP data were then processed through an automated SAS-based data verification system, Research Data Management and Quality Control System (RDMQ), for quality assurance (QA)/QC checking. After verification and validation by the PI, the data sets were output in a form specific for upload to GLENDA. Finally, these data sets were uploaded to GLENDA.

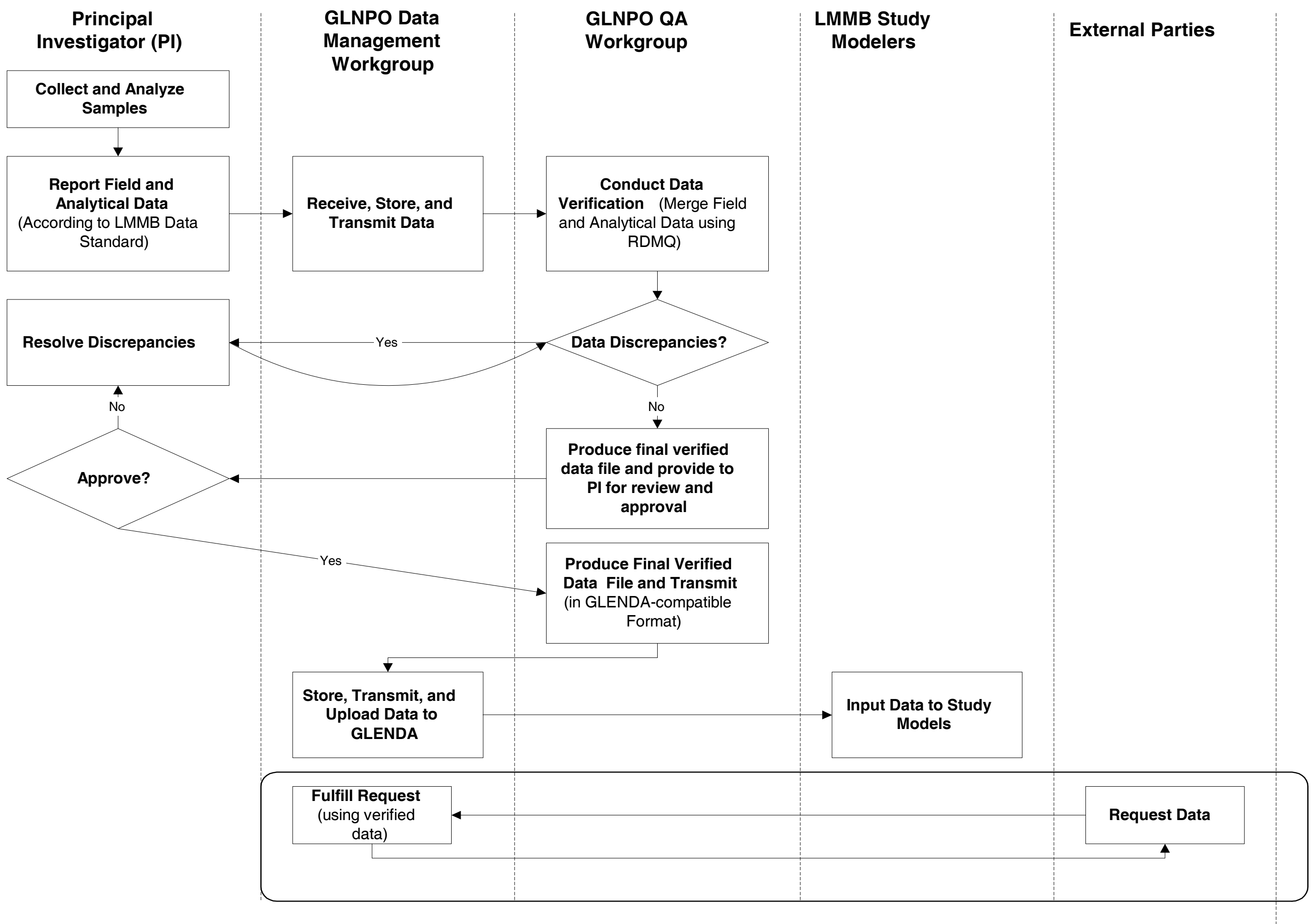

Figure 1.1.3. Flow of information in the LMMBP.

1.1.5.4.2 Great Lakes Environmental Monitoring Database

Central to the data management effort is a computerized database system to house LMMBP and other project results. That system, the Great Lakes Environmental Monitoring Database (GLENDA), was developed to provide data entry, storage, access, and analysis capabilities to meet the needs of mass balance modelers and other potential users of Great Lakes data.

Development of GLENDA began in 1993 with a logical model based on the modernized STORET concept and requirements analysis. GLENDA was developed with the following guiding principles:

- **True multi-media scope** – Water, air, sediment, taxonomy, fish tissue, fish diet, and meteorology data can all be housed in the database.
- **Data of documented quality** – Data quality is documented by including results of quality control parameters.
- **Extensive contextual indicators** – Ensure data longevity by including enough information to allow future or secondary users to make use of the data.
- **Flexible and expandable** – Database is able to accept data from any Great Lakes monitoring project.
- **National compatibility** – GLENDA is compatible with STORET and allows ease of transfer between these large databases.

In an effort to reduce the data administration burden and ensure consistency of data in this database, GLNPO developed several key tools. Features including standard data definitions, reference tables, standard automated data entry applications, and analytical tools are (or will soon be) available.

1.1.5.4.3 Public Access to LMMBP Data

All LMMBP data that have been verified (through the QC process) and validated (accepted by the PI) are available to the public. Currently, GLNPO requires that written requests be made to obtain the LMMBP data. The data sets are available in several formats including WK1, DBF, and SD2.

The primary reason for requiring an official request form for the LMMBP data is to keep track of requests. This allows GLNPO to know how many requests have been made, who has requested data, and what use they intend for the data. This information assists GLNPO in managing and providing public access to Great Lakes data and conducting public outreach activities. In the future, after all data are verified and validated, GLNPO intends to make condensed versions of the data sets available on the LMMBP web site for downloading. This will allow easy public access to the LMMBP data.

Further information on the information management for the LMMBP can be found in The Lake Michigan Mass Balance Study Quality Assurance Report (U.S. Environmental Protection Agency, 2001a).

1.1.5.5 Quality Assurance Program

At the outset of the LMMBP, managers recognized that the data gathered and the models developed from the study would be used extensively by decision-makers responsible for making environmental, economic, and policy decisions. Environmental measurements are never true values and always contain some level of uncertainty. Decision-makers, therefore, must recognize and be sufficiently comfortable with the uncertainty associated with data on which their decisions are based. In recognition of this requirement, the LMMBP managers established a QA program goal ofensuring that data produced under the LMMBP would meet defined standards of quality with a specified level of confidence.

The QA program prescribed minimum standards to which all organizations collecting data were required to adhere. Data quality was defined, controlled, and assessed through activities implemented within various parameter groups (e.g., organic, inorganic, and biological parameters). QA activities included the following:

- **QA Program** – Prior to initiating data collection activities, plans were developed, discussed, and refined to ensure that study objectives were adequately defined and to ensure that all QA activities necessary to meet study objectives were considered and implemented.

- **QA Workgroup** – USEPA established a QA Workgroup whose primary function was to ensure that the overall QA goals of the study were met.

- **QA Project Plans (QAPPs)** – USEPA worked with PIs to define program objectives, data quality objectives (DQOs), and measurement quality objectives (MQOs) for use in preparing Quality Assurance Project Plans (QAPPs). Principal investigators submitted QAPPs to the USEPA for review and approval. USEPA reviewed each QAPP for required QA elements and soundness of planned QA activities.

- **Training** – Before beginning data collection activities, PIs conducted training sessions to ensure that individuals working on the project were capable of properly performing data collection activities for the LMMBP.

- **Monthly Conference Calls and Annual Meetings** – USEPA, PIs, and support contractors participated in monthly conference calls and annual meetings to discuss project status and objectives, QA issues, data reporting issues, and project schedules.

- **Standardized Data Reporting Format** – PIs were required to submit all data in a standardized data reporting format that was designed to ensure consistency in reporting and facilitate data verification, data validation, and database development.

- **Intercomparison Studies** – USEPA conducted studies to compare performance among different PIs analyzing similar samples. The studies were used to evaluate the comparability and accuracy of program data.

- **Technical Systems Audits** – During the study, USEPA formally audited each PI's laboratory for compliance with their QAPPs, the overall study objectives, and pre-determined standards of good laboratory practice.

- **Data Verification** – PIs and the USEPA evaluated project data against pre-determined MQOs and DQOs to ensure that only data of acceptable quality would be included in the program database.

- **Statistical Assessments** – USEPA made statistical assessments of the LMMBP data to estimate elements of precision, bias, and uncertainty.

- **Data Validation** – USEPA and modelers evaluated the data against the model objectives.

Comparability of data among PIs participating in the LMMBP was deemed to be important for successful completion of the study. Therefore, MQOs for several data attributes were developed by the PIs and defined in the QAPPs. MQOs were designed to control various phases of the measurement process and to ensure that the total measurement uncertainty was within the ranges prescribed by the DQOs. MQOs were defined in terms of six attributes:

- **Sensitivity/Detectability** – The determination of the low-range critical value that a method-specific procedure can reliably discern for a given pollutant. Sensitivity measures included, among others, method detection limits (MDLs) as defined in 40 CFR Part 136, system detection limits (SDLs), or instrument detection limits (IDLs).

- **Precision** – A measure of the degree to which data generated from replicate or repetitive measurements differ from one another. Analysis of duplicate samples was used to assess precision.

- **Bias** – The degree of agreement between a measured and actual value. Bias was expressed in terms of the recovery of an appropriate standard reference material or spiked sample.

- **Completeness** – The measure of the number of samples successfully analyzed and reported compared to the number that were scheduled to be collected.

- **Comparability** – The confidence with which one data set can be compared to other data sets.

- **Representativeness** – The degree to which data accurately and precisely represent characteristics of a population, parameter variations at a sampling point, a process condition, or an environmental condition.

The PI-defined MQOs also were used as the basis for the data verification process. GLNPO conducted data verification through the LMMBP QA Workgroup. The workgroup was chaired by GLNPO's Quality Assurance Manager and consisted of QC Coordinators that were responsible for conducting review of specific data sets. Data verification was performed by comparing all field and QC sample results produced by each PI with their MQOs and with overall LMMBP objectives. If a result failed to meet predefined criteria, the QC Coordinator contacted the PI to discuss the result, verify that it was correctly reported, and determine if corrective actions were feasible. If the result was correctly reported and corrective actions were not feasible, the results were flagged to inform data users of the failure. These flags were not intended to suggest that data were not useable; rather they were intended to caution the user about an aspect of the data that did not meet the predefined criteria. Data that met all predefined requirements were flagged to indicate that the results had been verified and were determined to meet applicable MQOs. In this way, every data point was assigned one or more validity flags based on the results of the QC checks. GLNPO also derived data quality assessments for each LMMBP data set for a subset of the attributes listed above, specifically sensitivity, precision, and bias. The LMMBP modelers and the LLRS Database Manager also performed data quality assessments prior to inputting data into study models. Such activities included verifying the readability of electronic files, identifying missing data, checking units, and identifying outliers. A detailed description of the QA program is included in The Lake Michigan Mass Balance Project Quality Assurance Report (U.S. Environmental Protection Agency, 2001a). A brief summary of quality implementation and assessment is provided in each of the following parts.

1.1.6 Project Documents and Products

During project planning, LMMBP participants developed study tools including work plans, a methods compendium, QAPPs, and data reporting standards. Through these tools, LMMBP participants documented many aspects of the study including information management and QA procedures. Many of these documents are available on GLNPO's website at http://www.epa.gov/glnpo/lmmb.

The LMMBP Work Plan

Designers of the LMMBP have documented their approach in a report entitled Lake Michigan Mass Budget/Mass Balance Work Plan (U.S. Environmental Protection Agency, 1997a). The essential elements of a mass balance study and the approach used to measure and model these elements in the Lake Michigan system are described in the work plan. This document was developed based upon the efforts of many Federal and State scientists and staff who participated in the initial planning workshop, as well as PIs.

QA Program/Project Plans

The Lake Michigan Mass Balance Project: Quality Assurance Plan for Mathematical Modeling, Version 3.0 (Richardson *et al.*, 2004) documents the quality assurance process for the development and application of LMMBP models, including hydrodynamic, sediment transport, eutrophication, transport chemical fate, and food chain bioaccumulation models.

The Enhanced Monitoring Program QA Program Plan

The Enhanced Monitoring Program Quality Assurance Program Plan (U.S. Environmental Protection Agency, 1997b) was developed in 1993 to ensure that data generated from the LMMBP supported its intended use.

The LMMBP Methods Compendium

The Lake Michigan Mass Balance Project Methods Compendium (U.S. Environmental Protection Agency, 1997c, 1997d) describes the sampling and analytical methods used in the LMMBP. The entire three volumes are available on GLNPO's website mentioned above.

The LMMBP Data Reporting Formats and Data Administration Plan

Data management for the LMMBP was a focus from the planning stage through data collection, verification, validation, reporting, and archiving. The goal of consistent and compatible data was a key to the success of the project. The goal was met primarily through the development of standard formats for reporting environmental data. The data management philosophy is outlined on the LMMBP website mentioned above.

Lake Michigan LaMP

"Annex 2" of the 1972 Canadian-American Great Lakes Water Quality Agreement (amended in 1978, 1983, and 1987) prompted development of a Lake-wide Area Management Plan (LaMP) for each Great Lake. The purpose of these LaMPs is to document an approach to reducing input of critical pollutants to the Great Lakes and restoring and maintaining Great Lakes integrity. The Lake Michigan LaMP calls for basin-wide management of toxic chemicals.

GLENDA Database

Central to the data management effort is a computerized data system to house LMMBP and other project results. That system, the Great Lakes Environmental Monitoring Database (GLENDA), was developed to provide data entry, storage, access, and analysis capabilities to meet the needs of mass balance modelers and other potential users of Great Lakes data.

References

Richardson, W.L., D.D. Endicott, R.G. Kreis, Jr., and K.R. Rygwelski (Eds.). 2004. The Lake Michigan Mass Balance Project Quality Assurance Plan for Mathematical Modeling. Prepared by the Modeling Workgroup. U.S. Environmental Protection Agency, Office of Research and Development, National Health and Environmental Effects Research Laboratory, MED-Duluth, Large Lakes Research Station, Grosse Ile, Michigan. EPA/600/R-04/018, 233 pp.

U.S. Environmental Protection Agency. 1995a. National Primary Drinking Water Regulations, Contaminant Specific Fact Sheets, Inorganic Chemicals, Technical Version. U.S. Environmental Protection Agency, Office of Water, Washington, D.C. EPA/811/F-95/002-T.

U.S. Environmental Protection Agency. 1995b. National Primary Drinking Water Regulations, Contaminant Specific Fact Sheets, Synthetic Organic Chemicals, Technical Version. U.S. Environmental Protection Agency, Office of Water, Washington, D.C. EPA/811/F-95/003-T.

U.S. Environmental Protection Agency. 1997a. Lake Michigan Mass Budget/Mass Balance Work Plan. U.S. Environmental Protection Agency, Great Lakes National Program Office, Chicago, Illinois. EPA/905/R-97/018, 155 pp.

U.S. Environmental Protection Agency. 1997b. The Enhanced Monitoring Program Quality Assurance Program Plan. U.S. Environmental Protection Agency, Great Lakes National Program Office, Chicago, Illinois. EPA/905/R-97/017, 61 pp.

U.S. Environmental Protection Agency. 1997c. Lake Michigan Mass Balance Study (LMMB) Methods Compendium, Volume 1: Sample Collection Techniques. U.S. Environmental Protection Agency, Great Lakes National Program Office, Chicago, Illinois. EPA/905/R-97/012a, 1,440 pp.

U.S. Environmental Protection Agency. 1997d. Lake Michigan Mass Balance Study (LMMB) Methods Compendium, Volume 2: Organic and Mercury Sample Analysis Techniques. U.S. Environmental Protection Agency, Great Lakes National Program Office, Chicago, Illinois. EPA/905/R-97/012b, 532 pp.

U.S. Environmental Protection Agency. 1999. National Recommended Water Quality Criteria-Correction. U.S. Environmental Protection Agency, Office of Water, Washington, D.C. EPA/822/Z-99/001, 25 pp.

U.S. Environmental Protection Agency. 2001a. The Lake Michigan Mass Balance Study Quality Assurance Report. U.S. Environmental Protection Agency, Great Lakes National Program, Chicago, Illinois. EPA/905/R-01/013.

U.S. Environmental Protection Agency. 2001b. Ambient Aquatic Life Water Quality for Atrazine. U.S. Environmental Protection Agency, Office of Water, Washington, D.C. EPA/822/D-01/002, 230 pp.